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The Benefits of Computed Tomographic Colonography in Reducing a Long Colonoscopy Waiting List

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Abstract

Purpose: The Radiology Department, Royal Jubilee Hospital, Victoria, BC, with the support of gastroenterologists and surgeons, was awarded a BC Innovation fund to run a pilot project of computed tomographic colonography to reduce an unacceptably long 2-year colonoscopy waiting list. Funds were approved in April 2007 for a 1-year project, which was completed on March 31, 2008.
Methods: This article describes the challenges of delivering a high-volume computed tomographic colonography program at a busy community hospital, with discussion of the results for the 2,005 patients who were examined.
Results: Colonoscopy was avoided in 1,462 patients whose computed tomographic studies showed no significant lesions. In the remainder of patients, only lesions larger than 5 mm were reported, with a total of 508 lesions identified in 433 patients. There were 57 cancers of which 52 were reported as either definite or possible cancers, whereas 5 were not seen on initial scans. Some of the patients with cancer had been on the colonoscopy waiting list for 2 years. In addition, there were 461 patients with significant extracolonic findings, including 84 who required urgent or semi-urgent further management for previously unsuspected conditions, such as pneumonia, aneurysms larger than 5 cm, and a range of solid renal, hepatic, and pancreatic masses. There were no procedural complications from the computed tomographic colon studies.
Conclusions: We have shown that it is feasible to run a high volume CTC service in a general hospital given hospital support and funding. The benefits in this group of over 2000 patients included avoidance of colonoscopy in over 70% of patients, detection of significant polyps or cancer in approximately 20% of patients, and identification of clinically important conditions in 7%–18% depending on the definition used. The estimated costs including capital, operating, and professional fees were in the range of $400.

Résumé

Objet: Le département de radiologie, de l'hôpital Royal Jubilee de Victoria, en accord avec les équipes de gastroentérologie et de chirurgie, grâce au support financier de fonds provinciaux d'aide à l'innovation, a réalisé un projet pilote visant à utiliser la colonoscopie virtuelle ou coloscanner afin de réduire le temps d'attente inacceptable de 2 ans sur liste de colonoscopie. Le projet d'une durée de 1 an a débuté à l'arrivée des fonds en avril 2007 pour s'achever le 31 mars 2008.
Méthodes: L'objectif du propos porte sur la faisabilité de la mise en place d'une activité à débit élevé de coloscanner au sein d'une structure hospitalière générale et sur les résultats des 2 005 patients qui ont bénéficié de l'examen.
Résultats: 1462 patients n'ont pas bénéficié d'une colonoscopie en raison d'un coloscanner ne présentant pas de lésion significative. Seule les lésions de plus de 5 mm ont été décrites avec un total de 508 lésions détectées chez 433 patients. Parmi les 57 cancers colorectaux, 52 avaient été affirmés ou suspectés en colonoscopie virtuelle tandis que 5 n'avaient pas été détectés sur le scanner initial. Parmi les patients présentant un néoplasie colorectal, certains figuraient sur la liste d'attente pour une colonoscopie depuis deux ans. Par ailleurs, le coloscanner a permis de découvrir chez 461 patients des anomalies extra coliques qui dans 84 cas ont nécessité une prise en charge urgente ou semi urgente devant la découverte fortuite de pathologies telle que des pneumonies, des anévrismes de l'aorte abdominale de plus de 5 cm, des masses solides rénales, des masses hépatiques ou pancréatiques. Il n'a pas été observé de complication immédiate ou au décours des coloscanners.

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Conclusions: Nous avons prouvé qu'il est faisable pour fonctionner un service de CTC de grand volume dans un hôpital général donné l'appui et le placement de d'hôpital. Dans notre groupe de plus de 2000 clients, les avantages comportent d'éviter coloscopie dans plus de 70%, détection des polypes ou du cancer dans environ 20%, et identification des conditions médicalement importantes dans 7% à 18% selon la définition employé. Les coûts estimatifs comprenant capital, les frais d'exploitation et les honoraires professionnels étaient environ $400.

Key Words: CT colonography; Colonoscopy; Polyp; Colon cancer

Computed tomographic colonography (CTC) was invented in 1993 and has been evolving over the past 15 years [1]. Recent specialist center and multicenter trials demonstrated that CTC sensitivity for detection of advanced adenomas is equal to that of colonoscopy, and its sensitivity for cancer can exceed that of colonoscopy [2–4]. This superior accuracy and improved patient acceptance led many departments to replace barium enemas with CTC. An opportunity to help shorten an overly long optical colonoscopy waiting list provided the impetus to obtain funding to create a high-volume CTC service in Victoria.

We began the CTC service with patients drawn from the barium enema waiting list and then expanded to include patients waiting for optical colonoscopy as we developed the tools and training to handle up to 20 patients per day. By March 31, 2008, when the project terminated, we had examined 2,005 patients. Over the next few months, follow-up data were collected on colonoscopy and pathology findings.

Since April 2008, the CTC service has continued without specific funding at about 15 patients a day, divided between 2 hospitals in Victoria. Two formal CTC training workshops were held, and all the hospitals on Vancouver Island have been equipped with appropriate 3-dimensional (3D) CTC workstations networked to permit collaboration and consultation.

Methods

Equipment

Although it is clear that early generation multislice scanners can produce acceptable CTC images, we were fortunate in having 64-row scanners available because the examination is a little quicker and the images are sharper. Buscopan (Boehringer Ingelheim GmbH, Ingelheim, Germany) was not used initially, but, after evaluation in the first part of the study, it was then routinely used, given as 20 mgm intravenous before starting insufflation. For the rare patient with an absolute contraindication to the use of Buscopan, scans were performed either without an antispasmodic or with glucagon 1 mgm intravenous.

Scan Protocol

A small flexible rubber catheter was inserted per rectum, and the colon was distended with carbon dioxide by using a pressure-controlled pump (E-Z-EM Protoco$_2$l; E-Z-EM, Lake Success, NY). Adequate colon distension was confirmed by the technologist by examining scout views. Scans were acquired on one of two 64-channel computed tomography (CT) scanners: Sensation 64 (Siemens AG Healthcare, Erlangen, Germany) or Aquilion 64 (Toshiba Medical Systems, Tochigi-ken, Japan). Image data were acquired at the smallest available collimation (0.625 or 0.5 mm), with a reconstruction interval of 1 mm by using 120 kVp and 50 mA. Scans were obtained in the supine position for all patients and also either in the prone or decubitus positions. In some patients in whom adequate distension was not obtained in the first 2 scanning positions, a third sequence was obtained.

Image processing and interpretation was performed by using a Viatronix V3D Colon workstation (Viatronix Inc., Stony Brook, NY). Image interpretation was made primarily by using 3D images, with secondary use of 2-dimensional (2D) images. We selected a Viatronix workstation by taking advantage of its then unique ability to provide rapid visual confirmation of attenuation values during 3D fly-through assessment to identify at a glance whether a protuberance was soft tissue (polyp or cancer, although it cannot distinguish between these 2), rather than stool with tagging, lipoma, or mucus. A standard reading included 4 fly-throughs of the colon in 3D: 1 each way on supine and prone images, with 2D imaging for problem solving, and a final 2D examination of the noncolonic structures in the abdomen and pelvis.

Bowel Preparation

It became apparent very quickly that, without fecal tagging, there would be an unacceptably high rate of false-positive reports for smaller- and medium-sized polyps [5,6]. A combination of barium sulfate and water-soluble contrast was used, together with the purgatives PICO-SALAX (Ferring Pharmaceuticals, Saint-Prex, Switzerland) and Dulcolax (Boehringer Ingelheim GmbH). This combination worked moderately well, but a substantial minority (about 20%) of patients had a sticky coat of barium adherent to the colonic mucosa in places that interfered with visualization. Modifications to the preparation, including reduction in tagging-agent volumes and changes in the timing of the administration of purgatives, were successful in eliminating the sticky coat problem [7].

Radiologist Training

Three radiologists were trained before the project began. They were joined over the ensuing months by 9 others who attended workshops run by Pickhardt et al [4].

Carbon Dioxide Insufflations

Several studies showed that, in patients having colonoscopy or barium enema, postprocedural pain is caused by nitrogen retention associated with the use of room air, whereas, with carbon dioxide, there is no postprocedural pain [8,9]. In CTC, the 18 cases of perforation reported all occurred with staff-administered insufflation of room air [10,11], and, so far, there are no reports of perforation from automated insufflations of carbon dioxide. Carbon dioxide is rapidly absorbed, which makes it important to leave the insufflation machine turned on until the end of the examination so that gas is replenished and keeping the colon distended for both the supine and prone series. We are concerned that the lower rectum and anal canal may be obscured by the catheter tip and retention balloon [12,13], but it is not clear whether the enema tip can routinely be removed immediately before the final prone series without loss of distension.

Buscopan

Early on in the project, several cases of inadequate distension were noted. The literature was ambivalent about the role of intravenously administered Buscopan [14–17]. Our own study showed that its use was associated with improved distension, with an odds ratio of 7.8 of achieving optimal distension [18]. This was especially true in the presence of diverticular disease. Having confirmed its effectiveness, we avoided major delays in drug administration by using trained technologists [19] rather than nurses to inject Buscopan just before insertion of the enema tip. As an additional bonus, technologists noted that patients seemed more comfortable, and the time to full distension was reduced.

Referrals

Referrals from colonoscopists were solicited, with no restriction on whom the colonoscopists chose to refer. In general, they referred patients who had been on the waiting list the longest time. Most were screening and surveillance patients as well as the lower-risk symptomatic ones. On review of the indications, many of the screening and surveillance patients also had minor symptoms. Symptomatic patients were also accepted from family physicians because they could obtain a CTC more quickly than a gastroenterology consult.

Patients whose colonoscopies were incomplete were also accepted at first, until it became apparent that, without fecal tagging, there was an unacceptably high false-positive rate because of difficulty in distinguishing between stool and polyp, because stool does not always have the characteristic inhomogeneity. Our current bowel preparation with fecal tagging is acceptable to both colonoscopists and CT radiologists so that, if necessary, the 2 tests can be done on the same day in either order.

Table 1
Indications for computed tomographic colonoscopy

Group	Subgroup	Number (%)	Number (%)
Screening	No family Hx	509 (25.4)	984 (49.1)
	Family Hx of polyp/CRCA	475 (23.7)	
Surveillance	Previous polyp Hx	112 (5.6)	148 (7.4)
	Previous CRCA Hx	36 (1.8)	
Symptomatic	Abdominal mass	10 (0.5)	873 (43.5)
	Blood PR/+fobt	421 (21.0)	
	Weight loss	40 (2.0)	
	Change in BM	287 (14.3)	
	Abdominal pain	115 (5.7)	
Total			2,005

Hx = history; CRCA = colorectal carcinoma; PR = per rectum; fobt = fecal occult blood test; BM = bowel movement.

Results

Patient Population

Our study population included 2005 patients, with a mean age of 62 years and range of 22–94 years. The sex distribution was 59.6% women and 40.4% men. Approximately half of the patients were for screening and half were symptomatic, with only a few for surveillance, as shown in Table 1.

Findings

The lesions seen and reported on CT are summarized in Table 2 (see Follow-up Colon Investigations section for colonoscopy and pathology results for lesions that were investigated further).

Equivocal Reports Analysis

On a review of the 2,005 reports, there were 53 lesions in 50 patients in whom the findings were equivocal (possible mass, minor bowel-wall thickening, slight bowel-wall thickening because of stool or a lesion, a polyp cannot confidently be excluded) often associated with inadequate distension. The images from these cases were reviewed by experienced radiologists without knowledge of the follow-up

Table 2
Lesions seen on computed tomographic colonoscopy

Finding		No. lesions	No. patients
Lipoma		14	12
Polyp	6–9 mm	226	180
	10–19 mm	139	121
	20+ mm	36	32
	Total	401	333
Polyp (equivocal)	6–9 mm	3	3
	10–19 mm	11	11
	20+ mm	7	7
	Total	21	21
Cancer		40	37
Cancer (equivocal)		32	30

Table 3
Results of review of equivocal computed tomographic reports

	Radiologic opinion on review of images			
Final findings	Normal	Equivocal, needs colonoscopy	Definite diagnosis	Failed examination
Diverticular disease		5		
Cancer		2	4[a]	
Polyp	1[b]	5		
Other		1 SRUS	1 leiomyoma (GIST)	
Normal colonoscopy	12	7		2
No follow-up	5	3		1
Failed colonoscopy		1		

GIST = gastrointestinal stromal tumour; SRUS = solitary rectal ulcer syndrome.
[a] Three confirmed, 1 "hard, thick, scarred fold" with negative biopsy.
[b] A 6-mm serrated adenoma.

Table 4
Recommendations from computed tomographic colonoscopy (CTC) for further colon investigations

Investigation	Indication	No.	Total
None required	—	1,462	1,462
Colonoscopy	Suspected colonic neoplasms (polyp, cancer)	351	515
	Small-bowel polyp	1	
	Diverticular disease	17	
	Other colonic lesion	1	
	Colitis	2	
	Inadequate view, inadequate colonic distension	140	
	Inadequate view, artifact from hip prosthesis	3	
Repeated CTC	Need higher radiation dose because of obesity	1	28
	Inadequate bowel preparation	27	
Total			2,005

findings and categorized as one of the following: normal, equivocal needing colonoscopy, definite diagnosis, or failed examination and needs to be repeated. These allocations and the final diagnoses are shown in Table 3.

Among the equivocal cases, there were 5 definite diagnoses possible on radiologic review, 4 were subsequently confirmed. Of the 24 still found to be equivocal on review, 13 had abnormalities on colonoscopy, including 2 cancers, and 11 had no lesion found, 7 of these with normal colonoscopy. Among those thought to be normal on review, 13 had colonoscopy and 12 were indeed normal. These 50 cases with equivocal reports are thus a high-risk group, including 5 cancers and a leiomyoma (gastrointestinal stromal tumour), deserving of further review by an expert panel, perhaps as part of routine department policy.

Follow-up Colon Investigations

The follow-up colon investigations recommended after CTC for all 2,005 patients in the study are summarized in Table 4. Perhaps the most important finding is that, of the 2,005 patients examined, 1,462 did not require a colonoscopy and were removed from the waiting list. To assess the performance of the first year of CTC at our institution, surgical and pathology reports were obtained for all patients in this study who had colonoscopy. Most of the colonoscopies in this series were performed as a result of an abnormal CTC, but, in a few cases, the CTC was carried out as a result of an incomplete colonoscopy. In the latter cases, the colonoscopy reports were reviewed for CT false-positive analysis: if a lesion reported on CT was not seen in an adequately visualized region during the preceding colonoscopy, then the lesion was presumed to be a false positive. A summary of patients that were investigated via direct methods (endoscopy or laparotomy) and their indications based on CTC findings are summarized in Table 5.

The findings in the 382 patients who had colonoscopy and/or laparotomy were compared with the findings seen on CTC. The histologic type of all biopsied lesions was noted when it was available. The size of each lesion was recorded by using information in the following order of preference (when available): pathology, direct examination, and CT measurement. A lesion seen on CTC was called a true positive when a lesion of similar size and location was noted on direct examination, regardless of the histology of the lesion. A lesion seen on CT that was not seen on direct examination was called a false positive. A lesion larger than 5 mm found on direct examination that was not noted on CT was called a false negative. A summary of lesions seen on direct examination and lesions seen on CT that were subject to direct examination is found in Table 6. Lesions in this table include all that were suspicious for polyp, cancer, or other unknown mass.

In computing the numbers of CTC true and false positives and false negatives, we assumed that colonoscopy was perfect. In reality, studies have documented a false-negative rate of approximately 10% at optical colonoscopy, but we do not yet have adequately detailed follow-up to calculate that rate for our study. We are aware of at least 1 large (20-mm) intramural leiomyoma (gastrointestinal stromal tumour) and 1 ascending colon cancer that were missed on optical colonoscopy.

A total of 430 definite or equivocal lesions seen on CT were investigated via direct examination and 327 (76.0%) of these were found to be true positives (Table 6). Of the 387 definite calls, 305 (78.8%) were true positives. Of the 43 equivocal calls, 22 (51.1%) were true positives . From direct examination of 382 patients in the study, 362 lesions were found, and 35 (9.7%) of these were found to be false negatives. The histologic type for all 362 lesions found on direct examination and how these lesions were called on CTC are shown in Table 7.

We examined in detail the 5 patients in whom CTC did not initially detect carcinoma. Two of these were low rectal

Table 5
Patients who had computed tomographic colonoscopy and who had colonoscopy or laparotomy

CT result	CT detail	Not investigated	Partially investigated[a]	Fully investigated	Total
CT positive	Mass lesion	48	5	300	353
	Other lesion	2	0	0	2
CT indeterminate	Inadequate view	129	0	15	144
	Inadequate preparation	23	0	4	27
	DD[b]	13	0	4	17
CT negative		1,408	0	54	1,462
Total		1,623	5	377	2,005

CT = computed tomography; DD = diverticular disease.
[a]Patients with multiple lesions, some were visualized and others were not (eg, because of incomplete colonoscopy or surgical resection of only one affected region).
[b]Very severe DD, impairing complete evaluation.

Table 6
Summary of lesions seen on computed tomography vs direct examination

		Lesion on OC/lap	No lesion on OC	% true positive
Lesion on CT	6–9 mm	148	43	77.5
	10–19 mm	94	32	74.6
	20+ mm	63	7	90.0
Equivocal lesion on CT	6–9 mm	3	1	75.0
	10–19 mm	4	9	31.8
	20+ mm	15	11	57.7
Total		327	103	76.0

		Lesion on OC/lap
No lesion on CT	6–9 mm	19
	10–19 mm	10
	20+ mm	6
Total		35

CT = computed tomography; OC = optical colonoscopy; lap = laparotomy, 76.0% overall true positive.

cancers, 1 of which is not apparent even in retrospect, perhaps because it was a flat lesion further compressed by the retention balloon catheter. A third was a 10-mm sigmoid polyp that contained a focus of adenocarcinoma. The lesion was not well seen, even on review, because of diverticular disease and retained feces. The remaining 2 were ascending colon lesions that showed poor bowel preparation and poor distention. One of these patients had a repeated CTC, with a better cleansing, and the lesion was then seen. We noted that, other than a young patient with a compressed anorectal carcinoma, the mean age of the other 4 patients with missed cancers was 80 years. Extra attention to 2D images of the rectum and cecum in elderly patients with retained feces and poor distension should reduce this error rate.

Extracolonic Findings

We reported 2493 extra colonic findings in our 2005 patients, most of which were described as incidental and requiring no further workup. In 175 (7%), further investigation was recommended, including 60 semi-urgently (for example for solid renal, pancreatic or liver masses) and 24 urgently (4 pneumonia; 3 large, >5 cm aortic aneurysms; and 17 pleural or pericardial effusions). There were, in addition, 139 with renal calculi, 115 with gallstones, 198 with hernias of various types (32 nonhiatal), and 868 with various musculoskeletal abnormalities, mainly lumbar facet joint and degenerative disc disease. Including those with gallstones, renal calculi and nonhiatal hernias significant extracolonic findings were described in 461 or 18%.

Discussion

In addition to the importance of earlier detection of more than 50 colon cancers and several hundred significant polyps as well as critical extracolonic pathologies, the major impact for the 2005 patients examined by CTC is that 1462 had a normal examination and thus no longer occupied slots on the colonoscopy waiting list, depriving patients with disease of the opportunity of early diagnosis. As CTC becomes routinely available in all hospitals, endoscopists and radiologists will need to establish clinical guidelines to triage patients to a colonoscopy or CTC [2]. One example of a possible distribution, though the exact dividing point will vary from hospital to hospital, depending on availability of the different resources, and local expertise is shown in Table 8.

In general, there is little point in allowing patients with probable inflammatory bowel disease to have CTC. However, there is no point in allowing low-risk patients to wait for colonoscopy when CTC can select out the 80% without significant polyps. A recent review of CTC as a screening tool concluded that it would be less cost effective than colonoscopy, unless the cost could be reduced below CD$662 per patient [20,21]. A realistic goal of $400 per patient would render primary CTC screening a very cost-effective method of screening. Furthermore, the colonoscopy waiting lists are so long that CTC has a great dealt to offer in preventing patients with early cancer from progressing to incurable disease while waiting for their colonoscopy.

Although a system is proposed (see Table 8) to triage patients to either CTC or colonoscopy, some patients will have to undergo both examinations. CTC for screening will be more readily accepted if we ensure that therapeutic colonoscopy can occur on the same day as a positive CTC examination so that patients only have to endure 1 bowel preparation. Conversely, for patients triaged to colonoscopy, the option of having same-day CTC in the event of incomplete colonoscopy may reduce heroic efforts to reach the cecum in difficult cases, resulting in less patient discomfort and lower risk of perforation. Whether CTC is to follow colonoscopy or vice versa, a common bowel preparation regime is required that does not interfere with visualization during colonoscopy and includes fecal tagging to avoid false positives on CTC. During this project, we experimented with different bowel preparation regimes and currently have 1 that is satisfactory for both CTC and colonoscopy [7].

Table 7
Histologic type of lesions found on direct examination and how they were called on computed tomography (CT)

Histologic type	How lesions were called on CT						
	Polyp	Cancer	Equivocal, polyp	Equivocal, cancer	Lipoma	Missed	Total
Other benign	22	2	2	9	0	0	35
Not analysed[a]	10	0	0	0	5	0	15
Hyperplastic	20	0	1	0	0	2	23
Juvenile	1	0	0	0	0	0	1
Serrated	11	0	1	0	0	1	13
Tubular, <10 mm	80	0	1	0	0	12	93
Tubular, 10+ mm	43	0	1	0	0	9	53
Tubulovillous	54	1	1	0	0	5	61
Villous	2	1	1	0	0	0	4
High-grade dysplasia	4	1	1	0	0	1	7
Carcinoma	18	30	0	4	0	5	57
Total	265	35	9	13	5	35	362

[a] No pathology available because of unretrieved or insufficient tissue.

Table 8
Potential patient allocations to computed tomographic colonoscopy (CTC) and colonoscopy

	CTC	Colonoscopy
Incomplete colonoscopy	++	
Screening normal risk	++	
Screening mild family history	++	
Minor lower-GI symptoms	++	
Surveillance	++	
Positive guaiac	++	+/−
Positive iFOBT	+/−	+/−
Major bowel symptoms	+/−	++
HNPCC		++
Highly probable neoplasm		++
Cancer for biopsy		++
Acute lower-GI bleed (or CT angiogram)		++
Suspect IBD		++
Diarrhoea		++

GI = gastrointestinal; iFOBT = immunochemical fecal occult blood test; HNPCC = hereditary non-polyposis colorectal cancer; IBD = inflammatory bowel disease.

The demand for CTC service is high. Since our project has finished, the publicity engendered has increased the CTC waiting list to 6 months. Each year, 5,000 colonoscopies and 1,500 flexible sigmoidoscopies are performed in Victoria. We estimate that, if CTC is to play a role in reducing the colonoscopy waiting list, then there will be a need for in excess of 3,500 CTC examinations a year. Primary CTC screening in a center the size of greater Victoria (approximately 300,000) at ages 55 and 65 years, would require 7,500 CTC examinations a year with 100% patient participation or, more realistically, 5,000 examinations with 66% uptake. Large population colon cancer screening should consider the example of screening mammography programs, in which free-standing centers outside hospitals were set up to facilitate greater efficiency and reduced cost as well as greater patient acceptance. We think that outpatient CTC clinics in all major population centers will be a more efficient and cost-effective way to handle the case load rather than trying to push a large volume of relatively healthy outpatients through an already full hospital CT service.

Despite the high demand for CTC, funding is lacking. There is no technical fee or professional fee in place for CTC other than in Quebec. Simply replacing the barium enema service with CTC will be difficult enough in the present economic times, and to take on the numbers required to reduce colonoscopy waiting lists or provide screening will simply not be possible without increased funding.

Errors

The overall results from our initial start-up year were not as good as those from experienced specialist centers. The specificity of our diagnoses of polyps was 79% (305 of 387 polyps reported were confirmed). It was our deliberate policy to encourage overcalling during this start-up year to minimize false negatives, and this also led to more equivocal reports. Advanced adenomas are defined as those adenomas more than 9 mm in diameter and, in addition, any adenomas with at least 25% villous component or that contained high-grade dysplasia. We detected 110 of 125 advanced adenomas in our patient population, achieving a sensitivity of 88%. Fifty-two of 57 cancers were detected, and 4 of the misses were because of perceptive error, because the lesions were visible in retrospect. Radiologist experience clearly played a role, because 4 of the 5 missed cancers occurred in the first half of the study, and the 1 in the second half was missed by a recently trained radiologist. Mistakes in radiology reporting are most commonly because of perceptive errors [22,23], with technical problems often contributing. We expect that our detection rate will improve as radiologists become more experienced and that false positives should decrease with the routine use of Buscopan, fecal tagging, and double reading of equivocal cases.

In our series of 2,005 patients, there were 50 cases in which the radiologist had difficulty determining whether the study was normal or abnormal, and issued an equivocal report. These cases constitute a high-risk group that deserve of further evaluation; they included 5 cancers, 6 polyps larger than 5 mm, 5 complex diverticular disease, a leiomyoma (GIST), and 1 solitary rectal ulcer syndrome. Moreover, expert review of the cases before consulting colonoscopy or pathology findings allowed 18 of the 50 to be called normal (Table 3), and, on follow-up, no lesions larger than 6 mm were seen. Possible solutions to these issues would be to have nurses or technologists routinely do the initial reading so that the patient can be referred to same-day colonoscopy if appropriate. In addition, a system should be developed to ensure that any equivocal report is flagged and subject to a departmental review. One way to achieve the latter would be a standardized reporting system such that radiologists have to

allocate all cases into standard categories or else say (a legitimate choice) that they are unable to categorize the case with confidence, thus triggering the review by colleagues.

Double reading has been documented to improve detection of abnormalities in barium enemas [22], mammography [24], and CTC [25,26]. It does not matter who the second readers are, so long as they are well trained. It is often not practical to have examinations read by 2 radiologists, but it is practical to have the technologist [24,25] or a nurse [26] (C. D. Johnson, personal communication, 2007) do the initial reading. Once the possible abnormality has been perceived, it can be assessed. In Canada, it is not common at present to have the technologist perform the initial reading, but this may become critical in centers where same-day colonoscopy is to be offered when CTC shows significant polyps or cancer.

Computer-aided diagnosis programs are evolving rapidly. It may be possible to have the initial read carried out by one of these software programs at the time of the examination, to alert the radiologist at once to those patients with significant lesions who may benefit from same-day colonoscopy. Currently available systems have not yet reached this stage [27].

Concern has been expressed about the ability of CTC to detect serrated adenomas, not only because they may pose a high risk for malignant development but also they tend to be flatter than tubular adenomas. It is reassuring, therefore, that CTC detected 12 of 13 serrated adenomas in our patients, missing only 1 that was 8 mm in diameter. Most advanced adenomas are larger than 10 mm in diameter. We found 6 adenomas with high-grade dysplasia, of which 2 were smaller than 10 mm and the others were 10, 20, 23, and 30 mm. Only 13 of 125 advanced adenomas were smaller than 10 mm.

Extracolonic Findings

The finding of extracolonic abnormalities is a bonus of CTC but one that may lead to additional morbidity from investigation of silent abnormalities that are of no clinical importance. We found that 7% of our study population required further investigations and up to 18% if one chose to include all gallstones, renal stones, and nonhiatal hernias. In the American College of Radiology Information Network (ACRIN) study, abnormalities that required further evaluation were found in 16% [3]. Chin et al [28] found clinically significant lesions in 7.4%, at a per-patient increased cost of $24 or 14%, although they noted that limiting reporting of extracolonic abnormalities to the aorta and kidneys would have reduced the number of subjects that required follow-up to 3% and the cost increase to 4.7%, without detriment to the clinical outcome. Gluecker [29] found the increased cost of extracolonic findings to be 6% or $34. There is, at present, no general agreement on a policy on reporting of extracolonic abnormalities. Chin et al [28] described the additional burden of follow-up of these findings as modest and suggests that they could be reduced further if clear clinical and radiologic criteria are developed to guide further investigation. These would need to be explicitly described in the CTC report.

Tolan [30] brings a different perspective to this issue; in an article on barium enema replacement by CTC in the symptomatic elderly, a very different group from a screening population. In 400 sick elderly patients, they found 23 noncolonic malignancies and previously unknown significant abnormalities in 24% of patients. Hara [31] found significant abnormalities in only 5% of a screening population. The conclusion of Tolan [30] is that the importance of the numerous noncolonic findings in elderly symptomatic patients makes a compelling case for substituting barium enema with CTC. Different reporting policies may be required for reporting CTC in elderly symptomatic patients compared with a screening program, to minimize the follow-up of insignificant lesions in a screening population.

This, in turn, raises the issue of whether CTC in the elderly patients, especially in symptomatic patients should only be performed with intravenous contrast enhancement, as suggested by Spreng [32]. We did not use contrast enhancement for any of our studies. A case can be made that, when CTC shows a carcinoma, a staging scan should be done at the same visit with contrast and with higher amperage. This will require the technologist to do an immediate reading and discuss with the radiologist the addition of the contrast study.

The CT Colonography Reporting and Data System (C-RADS) reporting system [33] offers 1 suggestion for allocating extracolonic lesions to a category that dictates whether follow-up is required, depending on local agreement among radiologists, surgeons, and gastroenterologists in a community. Alternatively, a more detailed model may be recommended by a national or provincial body but would still require local approval.

Conclusion

Our 1-year project to reduce the optical colonoscopy waiting list produced positive health outcomes with earlier detection of more than 50 cancers and more than 100 advanced adenomas whose removal has prevented many future cancers. In addition, the diversion of hundreds of patients from the colonoscopy list shortened the wait for other patients. Finally, clinically important unsuspected finding were detected in from 7%–18% of patients, depending on how clinical importance is defined.

We showed that it is feasible to train staff and to run a high-volume CTC service in a general hospital, given hospital support and funding. Initial concerns about adding up to 20 patients a day to the workload of a busy department with 2 scanners that were already fully booked were overcome by enthusiastic staff and funding of increased hours from the Innovation fund. Buscopan, carbon dioxide, and fecal tagging were essential technical components of the examination, as was a workstation that provided quality images in 2D and 3D with rapid visual display of attenuation

values. With a core of trained radiologists and technologists, it has been possible to continue offering a lower volume service without additional funding.

However, a hospital is not the ideal site for a high-volume outpatient service, especially for screening and surveillance. A separate outpatient facility will enable less-expensive and more-efficient provision of outpatient CTC, much as with screening mammography. This will continue to help control the waiting list for colonoscopy and allow the hospital CTC service to concentrate on inpatients, symptomatic outpatients in poorer health, and those who have had incomplete colonoscopy.

Without funding, it is not feasible to run a service at the volumes required to contribute to population screening and keep colonoscopy wait lists at clinically appropriate levels for symptomatic patients. There must be either an addition to the global budget for the CT service, or a technical component available to the hospital and outpatient clinic for each patient who has a CTC examination. Activity-based funding has worked in some circumstances [34,35] and may be particularly appropriate to encourage the most cost-effective delivery of an outpatient service like CTC.

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